

Specification

CDMA Receiving Apparatus and Method

Technical Field

5                   The present invention relates to a wireless communication technique of a CDMA (Code Division Multiple Access) scheme and, more particularly, to a demodulation technique in a CDMA receiving apparatus used in a radio base station.

10   Background Art

                  In a CDMA communication system, when each user terminal communicates with a base station by using the CDMA scheme, they use, as uplink communication channels (to be referred to as CHs  
15   hereinafter), an individual CH occupied by each user and a shared CH shared among all users. In this case, in many CDMA communication systems, an individual CH of each user and a shared CH are code-multiplexed with each other. At the time of  
20   demodulation, such a multiplexed channel is demultiplexed into an individual CH and a shared CH for each user to perform demodulation.

                  In this case, an individual CH is formed for each slot, the start timing of each slot is  
25   independently determined for each user at the time of call connection. Each slot comprises a Pilot portion and a Data portion. The Pilot portion accommodates a

known symbol sequence determined for each slot in advance and is used to obtain a channel estimation value necessary for the demodulation of the Data portions of the individual CH and shared CH. The  
5 Data portion accommodates user data.

Since a shared CH is shared among all the users, although it is formed on a slot basis like an individual CH, the start timing is common to all the users and set in advance. The shared CH comprises  
10 only a Data portion. The Data portion accommodates user data. Since no Pilot portion exists in the shared CH, the shared CH can accommodate more user data than the individual CH.

It is obvious from the above description  
15 that the slot start timing difference between an individual CH and a shared CH changes for each user and is determined at the time of call connection. This is defined as a timing offset.

Conventionally, as a CDMA receiving  
20 apparatus used in such a CDMA communication system, an arrangement like that shown in Fig. 4 has been proposed (see, for example, Japanese Patent Laid-Open Nos. 2003-069451 and 2002-111570). This CDMA receiving apparatus comprises a reception antenna  
25 unit RA, a radio reception unit RX, and a plurality of user demodulation blocks. Although Fig. 4 shows only a user k demodulation block 1, other user

demodulation blocks have similar arrangements.

The radio reception unit RX receives a signal in the radio band which is received by the reception antenna unit RA, performs processing such as amplification of the input signal, frequency conversion from the radio band to the baseband, quadrature detection, and analog/digital conversion, and outputs the result to the user k demodulation block 1. The user k demodulation block 1 comprises a path detection circuit 10, individual CH path demodulation units 1A to 1L, an individual CH RAKE combining circuit (to be referred to as a RAKE combining circuit) 14, shared CH path demodulation units 2A to 2L, and a shared CH RAKE combining circuit (to be referred to as a RAKE combining circuit) 24.

The path detection circuit 10 receives an output from the radio reception unit RX, detects the path delay of a user k individual CH signal with respect to the input signal, and notifies the individual CH path demodulation units 1A to 1L and the shared CH path demodulation units 2A to 2L of the path delay. In this case, the user A individual CH signal to the user k individual CH signal and the shared CH signal are multiplexed on the input signal, and multipath components of the respective signals which are produced by propagation delays are also

multiplexed on the input signal.

As a method of multiplexing user individual CH signals and a shared CH, CDMA is generally used. However, TDMA (Time Division Multiple Access) can  
5 also be used to multiplex user individual CH signals. There are no limitations on a method of demultiplexing a plurality of multiplexed user signals, a method of detecting the path delays of multipath components, and the number of path delays  
10 to be detected.

In each of the individual CH path demodulation units 1A to 1L, an individual CH despreading circuit (to be referred to as a despreading circuit) 11 receives a radio reception  
15 output from the radio reception unit RX and the path delay of an individual CH path notified from the path detection circuit 10, and performs despreading operation for the radio reception output from the radio reception unit RX, thereby extracting a signal  
20 corresponding to a user k individual CH path. In addition, a channel estimation circuit (to be referred to as an estimation circuit hereinafter) 12 performs channel estimation on the basis of an output from the despreading circuit 11.

25 An individual CH demodulation circuit (to be referred to as a demodulation circuit hereinafter) 13 then receives an output from the despreading

circuit 11 and a channel estimation value as an  
output from the estimation circuit 12, and  
demodulates the Data portion. With this operation,  
the Data portion is demodulated after the influence  
5 of the channel is removed therefrom by using a  
channel estimation value at the reception timing of  
the Data portion. The RAKE combining circuit 14  
RAKE-combines the outputs from the individual CH path  
demodulation units 1A to 1L and outputs the user k  
10 individual CH demodulation result.

In each of the shared CH path demodulation  
units 2A to 2L, a shared CH despreading circuit (to  
be referred to as a despreading circuit hereinafter)  
21 receives a radio reception output from the radio  
15 reception unit RX and the path delay of an individual  
CH path which is notified from the path detection  
circuit 10, and performs despreading operation for  
the radio reception output from the radio reception  
unit RX, thereby extracting a signal corresponding to  
20 the user k shared CH path. A shared CH demodulation  
circuit (to be referred to as a demodulation circuit  
hereinafter) 23 receives an output from the  
despreading circuit 21 and a channel estimation value  
from one of the estimation circuits 12 corresponding  
25 to the individual CH path demodulation units 1A to  
1L, and demodulates the Data portion of the shared  
CH.

With this operation, the Data portion of the shared CH is demodulated by removing the influence of the channel by using the transmission estimation value at the reception timing of the Data  
5 portion of the individual CH. The RAKE combining circuit 24 receives outputs from the shared CH path demodulation units 2A to 2L, RAKE-combines them, and outputs the user k shared CH demodulation result.

Fig. 5 shows an example of demodulating  
10 operation. As in this example, in demodulating the Data portions of an individual CH and shared CH, a channel estimation value is calculated first by using the Pilot portion of the individual CH. The Data portion of the individual CH is demodulated by  
15 removing the influence of the channel by using the channel estimation value of the self-slot or a channel estimation value at the reception timing of the Data portion which is obtained from the channel estimation values of the self-slot and several  
20 adjacent slots by interpolation. In addition, as in the case of the Data portion of the individual CH, the Data portion of the shared CH is demodulated by removing the influence of the channel by using the channel estimation value at the reception timing of  
25 the Data portion.

Uplink transmission power control is performed for each slot of an individual CH. Uplink

transmission power to a shared CH is determined by giving a fixed or variable power offset to the uplink transmission power to an individual CH. Therefore, uplink transmission power control on a shared CH is  
5 performed on a slot basis with a predetermined time lag defined by a timing offset. In addition, no uplink transmission power control may be performed on a shared CH. That is, in some case, uplink transmission power is kept constant.

10 In this case, uplink transmission power control is the operation of comparing the uplink reception SIR (Signal to Interference Ratio) in a base station with a predetermined threshold, performing uplink transmission power increase control  
15 if the SIR is smaller than the threshold, and performing uplink transmission power decrease control if the SIR is larger than the threshold. As in the above CDMA radio communication system, according to the scheme of transmitting user data by using a  
20 shared CH, radio resources can be efficiently used. In addition, since all the users can be scheduled at common timings, this system is also suitable for control on the delay time of each user data.

Disclosure of Invention

25 Problem to be Solved by the Invention

According to such a conventional technique, however, if a timing offset exists and uplink

transmission power control is executed, the demodulation accuracy of a shared CH deteriorates. With reference to Fig. 5 described above, consider a case wherein a timing offset exists between an individual CH and a shared CH and uplink transmission power control is executed.

Letting  $Tx(n)$  be a transmission signal of an individual CH in an arbitrary slot  $(n)$ , and  $H(n)$  be a phase/amplitude fluctuation due to a channel including fading of the individual CH, i.e., a channel estimation value, a reception signal  $Rx(n)$  of the individual CH can be expressed by

$$Rx(n) = H(n) \cdot Tx(n)$$

At the time of the demodulation of the individual CH, in order to restore  $Tx(n)$  in the above equation, the following computation is performed. In this case,  $H^*(n)$  represents the complex conjugate of  $H(n)$ .

$$Tx(n) = H^*(n) \cdot Rx(n)$$

Letting  $tx(n)$  be a transmission signal of a shared CH at an arbitrary slot number  $n$ , and  $h(n)$  be the channel estimation value of the shared CH, a reception signal  $rx(n)$  of the shared CH can be expressed as follows:

$$rx(n) = h(n) \cdot tx(n)$$

Assume that no timing offset exists. In this case, letting  $H(n)$  be the channel estimation



value of the individual CH in the arbitrary slot (n)  
 and  $A_{\text{OFFSET}}$  be a coefficient obtained from a  
 predetermined power offset  $P_{\text{OFFSET}}$  of the shared CH  
 corresponding to the individual CH, the channel  
 5 estimation value  $h(n)$  used for the demodulation of  
 the shared CH is calculated as follows:

$$h(n) = A_{\text{OFFSET}} \cdot H(n)$$

In order to restore  $tx(n)$  in the above  
 equation at the time of the demodulation of the  
 10 shared CH, the following computation is performed.  
 In this case, "\*" represents a complex conjugate.

$$\begin{aligned} tx(n) &= h^*(n) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot H^*(n) \cdot rx(n) \end{aligned}$$

If the slot number of a symbol of an  
 15 individual CH used for channel estimation shifts from  
 the slot number of a symbol of a shared CH, which is  
 to be demodulated, due to a timing offset as  
 indicated by a symbol  $m$  in Fig. 5, the above equation  
 is rewritten as follows:

$$\begin{aligned} 20 \quad tx(n) &= h^*(n) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot H^*(n + 1) \cdot rx(n) \end{aligned}$$

Letting  $\Delta$  be a coefficient obtained from a  
 reception power fluctuation due to uplink  
 transmission power control from the slot (n) to the  
 25 slot (n + 1), and  $\alpha$  be a channel fluctuation due to  
 the elapsed time from the slot (n) to the slot (n +  
 1),  $H(n + 1)$  is given by

$$H(n + 1) = \Delta \cdot (H(n) + \alpha)$$

As is obvious, therefore,  $h(n)$  obtained from  $H(n + 1)$  contains a reception power fluctuation due to uplink transmission power control.

5                   On the other hand, the symbol  $m$  of the shared CH contains only a channel fluctuation due to the elapsed time, but does not contain any reception power fluctuation due to uplink transmission power control. If, therefore, demodulation is performed by  
10 using the channel estimation value  $h(n)$  for the symbol  $m$  of the shared CH without any change, the demodulation accuracy of the shared CH deteriorates due to the influence of the reception power fluctuation caused by uplink transmission power  
15 control contained in  $h(n)$ .

$$\begin{aligned} tx(n) &= h^*(n) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot H^*(n + 1) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot \Delta \cdot (H(n) + \alpha)^* \cdot rx(n) \end{aligned}$$

In contrast to this, the following is an  
20 equation which is originally required. In this case, "\*" represents a complex conjugate.

$$tx(n) = A_{\text{OFFSET}} \cdot (H(n) + \alpha)^* \cdot rx(n)$$

It is also obvious from the above equation that an error corresponding to the coefficient  $\Delta$   
25 obtained from a reception power fluctuation due to uplink transmission power control at the time of the demodulation of the shared CH has occurred.

## Means of Solution to the Problem

The present invention has been made to solve such problems, and has as its object to provide a CDMA receiving apparatus and method which can  
5 prevent a deterioration in the demodulation accuracy of a shared CH even if a timing offset exists between an individual CH and a shared CH and uplink transmission power control is executed.

A CDMA receiving apparatus according to the  
10 present invention comprises a radio reception unit which outputs a radio reception output in an uplink communication channel on which an individual channel occupied by each user and a shared channel shared among all users are multiplexed on the basis of a  
15 CDMA scheme, by performing signal processing for a radio band signal received by a reception antenna, a channel estimation circuit which receives a signal corresponding to an individual channel of an arbitrary user which is obtained by performing  
20 despreading operation for the radio reception output, and calculates a channel estimation value indicating phase and amplitude fluctuations due to a channel from phase/amplitude information after despreading of a known Pilot portion symbol, a channel estimation  
25 value correction circuit which corrects the channel estimation value from the channel estimation circuit on the basis of a reception power fluctuation due to

uplink transmission power control which is caused by  
a timing offset between the individual channel of the  
user and the shared channel, and a shared channel  
demodulation circuit which demodulates a signal  
5 corresponding to the shared channel of the user which  
is obtained by performing despread operation for  
the radio reception output on the basis of the  
channel estimation value corrected by the channel  
estimation value correction circuit.

10 In addition, a CDMA receiving method  
according to the present invention comprises the  
radio reception step of outputting a radio reception  
output in an uplink communication channel on which an  
individual channel occupied by each user and a shared  
15 channel shared among all users are multiplexed on the  
basis of a CDMA scheme, by performing signal  
processing for a radio band signal received by a  
reception antenna, the channel estimation step of  
receiving a signal corresponding to an individual  
20 channel of an arbitrary user which is obtained by  
performing despread operation for the radio  
reception output, and calculating a channel  
estimation value indicating phase and amplitude  
fluctuations due to a channel from phase/amplitude  
25 information after despread of a known Pilot  
portion symbol, the channel estimation value  
correction step of correcting the channel estimation

value from the channel estimation circuit on the basis of a reception power fluctuation due to uplink transmission power control which is caused by a timing offset between the individual channel of the user and the shared channel, and the shared channel demodulation step of demodulating a signal corresponding to the shared channel of the user which is obtained by performing despread operation for the radio reception output on the basis of the channel estimation value corrected in the channel estimation value correction step.

#### Effects of the Invention

According to the present invention, since the data obtained by correcting a reception power fluctuation due to uplink transmission power control which is caused by the timing offset between an individual CH and a shared CH with respect to a channel estimation value in the individual CH is used for the demodulation of the shared CH, a deterioration in the demodulation accuracy of the shared CH can be prevented even if a timing offset exists and uplink transmission power control is executed.

#### Brief Description of Drawings

Fig. 1 is a block diagram showing the arrangement of a CDMA receiving apparatus according to an embodiment of the present invention;

Fig. 2 is a timing chart showing the operation of a CDMA receiving apparatus according to an embodiment of the present invention;

Fig. 3 is a timing chart showing another  
5 operation of the CDMA receiving apparatus according to an embodiment of the present invention;

Fig. 4 is a block diagram showing the arrangement of a conventional CDMA receiving apparatus; and

10 Fig. 5 is a timing chart showing the operation of the conventional CDMA receiving apparatus.

#### Best Mode for Carrying Out the Invention

An embodiment of the present invention will  
15 be described next with reference to the accompanying drawings.

#### [Outline of CDMA Receiving Apparatus]

A CDMA receiving apparatus according to this embodiment is a receiving apparatus used in a  
20 CDMA communication system comprising an individual channel (to be referred to as a CH hereinafter) which includes a Pilot portion and is used to perform uplink transmission power control and a shared CH which is used to perform demodulation by using the  
25 channel estimation value of the individual CH. In this apparatus, after channel estimation is performed from an individual CH, a reception power fluctuation

due to uplink transmission power control which is caused by the timing offset between the individual CH and the shared CH, and the resultant data is used for the demodulation of the shared CH.

5                   This embodiment is based on the assumption that when each user terminal communicates with a base station by using the CDMA scheme, the individual CH occupied by each user and the shared CH shared among all the users are used as uplink communication CHs.

10 Assume that the individual CH and shared CH of each user are code-multiplexed with each other, and can be demultiplexed at the time of demodulation. Note that a multiplex scheme other than CDMA can be applied to the present invention as long as the individual CH

15 and shared CH of each user are code-multiplexed with each other, and can be demultiplexed at the time of demodulation.

                  An individual CH is formed on a slot basis and the start timing of each slot is independently

20 determined for each user at the time of call connection. Each slot comprises a Pilot portion and a Data portion. The Pilot portion accommodates a known symbol sequence determined for each slot in advance and is used to estimate a channel necessary

25 for the demodulation of the Data portions of the individual CH and shared CH. The Data portion accommodates user data. Note that even when an

individual CH comprises only a Pilot portion, the present invention can be applied to this apparatus.

Since a shared CH is shared among all the users, although it is formed on a slot basis like an individual CH, the start timing is common to all the users and set in advance. The shared CH comprises only a Data portion. The Data portion accommodates user data. Since no Pilot portion exists in the shared CH, the shared CH can accommodate more user data than the individual CH. It is therefore obvious that the slot start timing difference between an individual CH and a shared CH, i.e., a timing offset, changes for each user and is determined at the time of call connection, and hence can be acquired for each user.

Uplink transmission power control is performed for each slot of an individual CH. Uplink transmission power to a shared CH is determined by giving a fixed or variable power offset to the uplink transmission power to an individual CH. In this case, uplink transmission power control is the operation of comparing the uplink reception SIR (Signal to Interference Ratio) in a base station with a predetermined threshold, performing uplink transmission power increase control if the SIR is smaller than the threshold, and performing uplink transmission power decrease control if the SIR is



larger than the threshold.

Uplink transmission power control on a shared CH is therefore performed on a slot basis with a predetermined time lag defined by a timing offset.

5 In addition, no uplink transmission power control may not be performed on a shared CH. That is, in some case, uplink transmission power is kept constant. A transmission power fluctuation in a user terminal which is generated in accordance with an uplink  
10 transmission power control command is directly observed as a reception power fluctuation in a base station. This makes it possible to estimate a reception power fluctuation due to uplink transmission power control in each slot from uplink  
15 transmission power control command information transmitted as a downstream signal.

In the CDMA receiving apparatus according to this embodiment, after channel estimation is performed from an individual CH, a reception power  
20 fluctuation due to uplink transmission power control which is caused by the timing offset between the individual CH and the shared CH, and the resultant data is used for the demodulation of the shared CH, thereby preventing a deterioration in the  
25 demodulation accuracy of the shared CH.

[Arrangement of CDMA Receiving Apparatus]

The CDMA receiving apparatus according to

an embodiment of the present invention will be described next with reference to Fig. 1. Note that the same reference numerals as in Fig. 4 described above denote the same or similar parts in the block diagram of Fig. 1 showing the CDMA receiving apparatus according to an embodiment of the present invention. The CDMA receiving apparatus in Fig. 1 comprises a reception antenna unit RA, a radio reception unit RX, and a plurality of user demodulation blocks. Although Fig. 1 shows only a user k demodulation block 1, other user demodulation blocks have similar arrangements. Note that both the number k of users and the number L of paths which can be demodulated are positive integers, and are not limited to any specific values.

The reception antenna unit RA comprises one or more reception antenna elements. Note that the number of reception antenna elements is not limited. In addition, no limitations are imposed on the directivity of each antenna element within the horizontal and vertical planes. For example, each antenna element may have omni-directivity or dipolar directivity.

The radio reception unit RX comprises a low-noise amplifier, band limiting filter, mixer, local oscillator, AGC (Auto Gain Controller), quadrature detector, low-pass filter, analog/digital

converter, and the like (not shown). The radio reception unit RX receives a signal in the radio band which is received by the reception antenna unit RA, performs amplification of the input signal, frequency  
5 conversion from the radio band to the baseband, quadrature detection, analog/digital conversion, and the like, and outputs the resultant data to the user k demodulation block 1.

The user k demodulation block 1 comprises a  
10 path detection circuit 10, a reception power difference correction coefficient calculation circuit (to be referred to as a correction coefficient calculation circuit hereinafter) 20, individual CH path demodulation units 1A to 1L, a RAKE combining  
15 circuit 14, shared CH path demodulation units 2A to 2L, and a RAKE combining circuit 24.

The path detection circuit 10 receives an output from the radio reception unit RX, detects the path delay of a user k individual CH signal with  
20 respect to the input signal, and notifies the individual CH path demodulation units 1A to 1L and the shared CH path demodulation units 2A to 2L of the path delay. In this case, the user A individual CH signal to the user k individual CH signal and the  
25 shared CH signal are multiplexed on the input signal, and multipath components of the respective signals which are produced by propagation delays are also

multiplexed on the input signal.

As a method of multiplexing user individual CH signals and a shared CH, CDMA is generally used. However, TDMA (Time Division Multiple Access) can  
5 also be used to multiplex user individual CH signals. There are no limitations on a method of demultiplexing a plurality of multiplexed user signals, a method of detecting path delays, and the number of path delays to be detected.

10 The correction coefficient calculation circuit 20 receives the timing offset information of the user k and the uplink transmission power control command information for the user k, and outputs a reception power difference correction coefficient for  
15 correcting a reception power fluctuation due to uplink transmission power control which is caused by a timing offset. A reception power difference correction coefficient for correcting a reception power fluctuation is calculated by estimating a  
20 reception power fluctuation corresponding to an uplink transmission power control command in a timing offset interval.

In this case, if the uplink transmission power of a shared CH is determined by providing a  
25 fixed or variable power offset ( $P_{\text{OFFSET}}$ ) with respect to the uplink transmission power of an individual CH, a reception power difference correction coefficient

can also be calculated in consideration of the power offset. Note that a reception power difference correction coefficient is calculated from the timing offset information of the user k and the uplink  
5 transmission power control command information of the user k regardless of the path.

Each of the individual CH path demodulation units 1A to 1L comprises a despreading circuit 11, estimation circuit 12, and demodulation circuit 13.  
10 The despreading circuit 11 receives a radio reception output from the radio reception unit RX and the path delay of the individual CH notified from the path detection circuit 10, performs despreading operation for the output from the radio reception unit, and  
15 extracts a signal corresponding to the individual CH of the user k.

The estimation circuit 12 receives the output from the despreading circuit 11 and calculates a channel estimation value indicating a  
20 phase/amplitude fluctuation due to the channel from the phase/amplitude information obtained after despreading of a known Pilot portion symbol. This channel estimation value changes for each path, and is used for the demodulation of the individual CH  
25 portion provided for the individual CH demodulation circuit and provided for a channel estimation value correction circuit (to be referred to as a correction

circuit) 22. This channel estimation value can be obtained from the Pilot portion symbol of the self-slot or the channel estimation values of the self-slot and several adjacent slots by  
5 interpolation. Note that no limitations are imposed on the number of slots to be used and an interpolation method to be used.

When a channel estimation value is provided for the correction circuit 22, the hard decision  
10 result on the Data portion of the individual CH can be handled in the same manner as a Pilot portion symbol, and a channel estimation value can be calculated from phase/amplitude information after despreading operation for the hard decision result on  
15 the Data portion symbol of the individual CH. Using this method makes it possible to improve the accuracy of a channel estimation value at the reception timing of a shared CH.

The demodulation circuit 13 receives an  
20 output from the despreading circuit 11 and a channel estimation value as an output from the estimation circuit 12, and demodulates the Data portion. The Data portion is demodulated by removing the influence of the channel by using a channel estimation value at  
25 the reception timing of the Data portion. A RAKE combining circuit 14 combines outputs from the individual CH path demodulation units 1A to 1L and

outputs the user k individual CH demodulation result.

Each of the shared CH path demodulation units 2A to 2L comprises a despreading circuit 21, the correction circuit 22, and a demodulation circuit 23. The despreading circuit 21 receives a radio reception output from the radio reception unit RX and the path delay of an individual CH which is notified from the path detection circuit 10, performs despreading operation for the radio reception output from the radio reception unit RX, and extracts a signal corresponding to the user k shared CH path.

The correction circuit 22 receives a channel estimation value as an output from the estimation circuit 12 and a reception power difference correction coefficient as an output from the correction coefficient calculation circuit 20, and calculates and outputs a corrected channel estimation value by applying the reception power difference correction coefficient to the channel estimation value. Since a channel estimation value changes for each path, a corrected channel estimation value is calculated for each path.

The demodulation circuit 23 receives an output from the despreading circuit 21 and corrected channel estimation values from the individual CH path demodulation units 1A to 1L, and demodulates the Data portion of a shared CH. With this operation, the

Data portion of the shared CH is demodulated by removing the influence of the channel by using the channel estimation value at the reception timing of the Data portion of the individual CH. The RAKE combining circuit 24 receives outputs from the shared CH path demodulation units 2A to 2L, and RAKE-combines the outputs, thereby outputting the user k shared CH demodulation result.

[Operation of CDMA Receiving Apparatus]

10                   The operation of the CDMA receiving apparatus according to this embodiment will be described next with reference to Fig. 2.

Assume that, as indicated by the flowchart of Fig. 2, first of all, a timing offset exists between an individual CH and a shared CH and a channel estimation value in an arbitrary path of an arbitrary user k for which uplink transmission power control is executed is to be corrected. Letting  $Tx(n)$  be a transmission signal of an individual CH in an arbitrary slot (n), and  $H(n)$  be a channel estimation value as an output from the estimation circuit 12, a reception signal  $Rx(n)$  of the individual CH can be expressed by

$$Rx(n) = H(n) \cdot Tx(n)$$

25                   At the time of demodulation, in order to restore  $Tx(n)$  in the above equation, the following computation is performed in the demodulation circuit



13. In this case,  $H^*(n)$  represents the complex conjugate of  $H(n)$ .

$$Tx(n) = H^*(n) \cdot Rx(n)$$

Letting  $tx(n)$  be a transmission signal of a  
5 shared CH at an arbitrary slot number  $n$ , and  $h(n)$  be the channel estimation value of the shared CH, a reception signal  $rx(n)$  of the shared CH can be expressed as follows:

$$rx(n) = h(n) \cdot tx(n)$$

10 Assume that no timing offset exists between an individual CH and a shared CH. In this case, letting  $H(n)$  be the channel estimation value of the individual CH in the arbitrary slot  $(n)$  and  $A_{\text{OFFSET}}$  be a coefficient obtained from a predetermined power  
15 offset  $P_{\text{OFFSET}}$  of the shared CH corresponding to the individual CH, the channel estimation value  $h(n)$  used for the demodulation of the shared CH is calculated as follows:

$$h(n) = A_{\text{OFFSET}} \cdot H(n)$$

20 In order to restore  $tx(n)$  in the above equation at the time of the demodulation of the shared CH, the following computation is performed in the demodulation circuit 23. In this case, "\*" represents a complex conjugate.

$$\begin{aligned} 25 \quad tx(n) &= h^*(n) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot H^*(n) \cdot rx(n) \end{aligned}$$

If the slot number of a symbol of an

individual CH used for channel estimation shifts from the slot number of a symbol of a shared CH, which is to be demodulated, due to a timing offset as in the case of a symbol  $m$ , the above equation is rewritten  
5 as follows:

$$\begin{aligned} tx(n) &= h^*(n) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot H^*(n + 1) \cdot rx(n) \end{aligned}$$

Letting  $\Delta$  be a coefficient obtained from a reception power fluctuation due to uplink  
10 transmission power control from the slot  $(n)$  to the slot  $(n + 1)$ , and  $\alpha$  be a channel fluctuation due to the elapsed time from the slot  $(n)$  to the slot  $(n + 1)$ ,  $H(n + 1)$  is given by

$$H(n + 1) = \Delta \cdot (H(n) + \alpha)$$

15 As is obvious, therefore,  $h(n)$  obtained from  $H(n + 1)$  contains a reception power fluctuation due to uplink transmission power control. On the other hand, the symbol  $m$  of the shared CH contains only the channel fluctuation due to the elapsed time,  
20 but does not contain any reception power fluctuation due to uplink transmission power control.

In this embodiment, the correction coefficient calculation circuit 20 calculates a reception power difference correction coefficient for  
25 correcting a reception power fluctuation due to uplink transmission power control which is caused by a timing offset from the timing offset information of

the user  $k$  and uplink transmission power control  
command information. The correction circuit 22  
calculates a corrected channel estimation value by  
applying the reception power difference correction  
5 coefficient to the channel estimation value.

More specifically, first of all, the timing  
offset information of the user  $k$  is acquired and  
input to the correction coefficient calculation  
circuit 20. In this case, a timing offset is  
10 determined at the time of call connection. In  
addition, uplink transmission power control command  
information which is transmitted as a downstream  
signal in the interval from the start of reception of  
the slot  $(n)$  of the user  $k$  to the start of reception  
15 of the slot  $(n + 1)$  is acquired and input to the  
correction coefficient calculation circuit 20.

The correction coefficient calculation  
circuit 20 then estimates a reception power  
fluctuation due to uplink transmission power control  
20 from the slot  $(n)$  of the user  $k$  to the slot  $(n + 1)$   
by using the uplink transmission power control  
command information transmitted as a downstream  
signal in the interval from the start of reception of  
the input slot  $(n)$  of the user  $k$  to the start of  
25 reception of the slot  $(n + 1)$ . In this case, it is  
thought that a transmission power fluctuation in the  
user terminal which occurs in accordance with the

uplink transmission power control command is directly observed as a reception power fluctuation in a base station.

Letting CTPC be a reception power fluctuation coefficient estimated from the total sum of pieces of transmission power control command information transmitted as downstream signals, and  $\Delta$  be a coefficient obtained from a reception power fluctuation due to uplink transmission power control from the slot (n) to the slot (n + 1), the following approximate expression holds:

$$\text{CTPC} \doteq \Delta$$

The correction coefficient calculation circuit 20 then calculates a reception power difference correction coefficient  $\beta$  which cancels out a reception power fluctuation due to uplink transmission power control in a timing offset interval by using a timing offset and an estimated reception power fluctuation due to uplink transmission power control, and outputs the calculated coefficient to the correction circuit 22.

$$\beta = \text{CTPC} - 1 \text{ (inside the timing offset interval)}$$

$$\beta = 1 \text{ (outside the timing offset interval)}$$

The correction circuit 22 calculates a corrected channel estimation value by applying a reception power difference correction coefficient to the channel estimation value as an output from the

estimation circuit 12. In this case, letting  $hc(n)$  be a corrected channel estimation value,  $hc(n)$  is represented by

$$hc(n) = A_{\text{OFFSET}} \cdot \beta \cdot H(n + 1)$$

5                   Using the corrected channel estimation value for the demodulation of the symbol  $m$  in Fig. 2 makes it possible to remove the influence of reception power fluctuation due to uplink transmission power control which is caused by a  
10   timing offset.

$$\begin{aligned} tx(n) &= hc^*(n) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot \beta \cdot H^*(n + 1) \cdot rx(n) \\ &= A_{\text{OFFSET}} \cdot \beta \cdot \Delta \cdot (H(n) + \alpha)^* \cdot rx(n) \\ &\doteq A_{\text{OFFSET}} \cdot (H(n) + \alpha)^* \cdot rx(n) \end{aligned}$$

15                   Since the following is an expression which is essentially required:

$$tx(n) = A_{\text{OFFSET}} \cdot (H(n) + \alpha)^* \cdot rx(n)$$

As is obvious from the above equation, an error at the time of demodulation of a shared CH can  
20   be removed. In this case, "\*" represents a complex conjugate.

In this manner, after channel estimation is performed from an individual CH, a reception power fluctuation due to uplink transmission power control  
25   which is caused by the timing offset between the individual CH and the shared CH is corrected, and the resultant data is used for the demodulation of the

shared CH. Even if, therefore, a timing offset exists between the individual CH and the shared CH and uplink transmission power control is executed, a deterioration in the demodulation accuracy of the shared CH can be prevented.

In this case, as shown in Fig. 3, this technique can be applied to a case wherein in the demodulation of the Data portion of a shared CH, the result obtained by performing weighted averaging of channel estimation values at reception timings near the Data portion is used as a channel estimation value at the reception timing of the Data portion. In this case, the influence of a reception power fluctuation due to uplink transmission power control which is caused by a timing offset can be removed by performing weighted averaging after a reception power difference correction coefficient is applied to each channel estimation value.

#### Industrial Applicability

The present invention is suitable for CDMA receiving apparatuses used in radio base stations constituting a mobile communication network such a cell phone network.